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Assessing diet and animal mobility in Iron Age Languedoc, southern France: New insights from a multiproxy approach

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ABSTRACT

The societies living in the present-day Languedoc region during the Iron Age (7th-2nd c. BC) experienced a series of progressive transformations, including a demographic growth and an increase in social differentiation, affecting their economic, social and political structure. This context certainly influenced economic organisation, including farming strategies. However, the relationship between animal husbandry and the economical and political context is not completely understood in Iron Age Languedoc. Two key issues – the feeding strategies and the animal mobility in the hinterlands of Languedoc – are poor known. With the aim of providing new insights into our understanding of animal diet and mobility, we combined zooarchaeology (species representation and mortality profiles), dental microwear, dental mesowear and isotopes –strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$)– on domestic ungulates from five major Iron Age sites: Cayla de Mailhac, La Ramasse, Le Cailar, La Monédière and *Lattara*. The combination of these approaches enabled us to support the hypothesis of a local breeding of livestock, the animal pasture in nearby areas to the site, and the different animal management between caprines and cattle.

1. Introduction

The protohistoric communities living in the Languedoc region (southern France) underwent a series of progressive transformations during the Iron Age (7th-2nd century BC). These transformations, driven by internal and external dynamics, affected their economic, social and political structures (Py, 1993, 1995; Gailledrat, 1997a, 2013, 2014). The emergence of local elites, who resided in fortified and walled villages (i.e., *oppida*) located on hilltops, suggests increased social differentiation (Dedet, 1992, 1995; Janin, 1993; Garcia, 1993, 1995, 2014; Bagan, 2007; Sanmartí, 2004; Sanmartí and Santacana, 2005; Beylier, 2012, 2014). Archaeologically, this view is supported by the presence of warrior equipment, weapons, and prestige goods. The material culture (e.g., burial trousseaus and differences in architecture) also shows the presence of social inequalities. This circumstance involved tensions between local elites, the protection of boundaries between territories, and the spread of warfare (Py, 1993; Gailledrat, 1997a, 2013, 2014).

This context certainly influenced economic organisation, including farming strategies. However, the relationship between livestock husbandry and the political and social framework in Iron Age Languedoc is still not fully understood. The strategies employed by herders/farmers to feed livestock and their use of the landscape, a key issue for understanding livestock management approaches, are poorly known. Several authors have suggested that animals with a more flexible diet, such as

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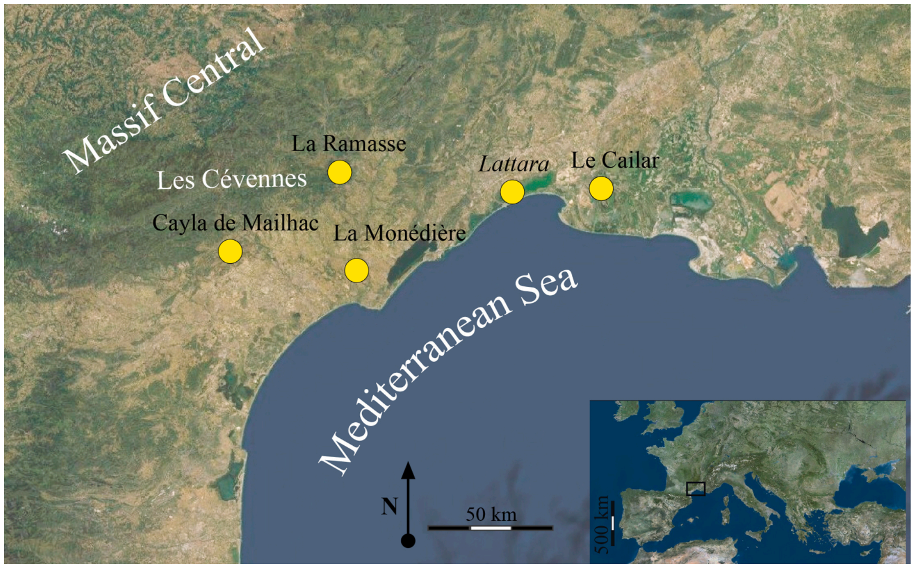

Fig. 1. Location of the settlements analysed in the Languedoc region (southern France).

caprines, would have been kept in more wooded areas or scrubland. In turn, cattle, which need more fresh grazing, would have been kept in grassland areas (Columeau, 2002; Gardeisen, 2010; Colominas et al., 2011; Nieto-Espinet et al., 2020). The taxonomic representation seems to be adapted to each particular geographical area: cattle were slightly more abundant in coastal sites, while sheep and goats were more common in inland sites (Gardeisen, 2010; Nieto-Espinet et al., 2020). This could be explained by the ecological requirements of each species: cattle generally need more water and fresh grazing, while caprines adapt better to arid conditions and are more sensitive to humidity and bacteria (e.g., Dupieux, 1998; Vincent and Holder, 2008; Rosa García et al., 2012; Thulliez and Mageur, 2018; Nieto-Espinet et al., 2020). Thus, the coastal areas could have been more suitable for cattle management since natural freshwater marshes abounded on the coast of the Gulf of Lion (e.g., Chabal, 2007; Ponel and Rocq, 2007), as is true for the present-day Regional Park of the Camargue (Ducan and d'Herbes, 1982). The reconstruction of animal diets, by combining isotope and dental wear analyses, could shed new light on this issue. However, few studies have addressed this in this particular geochronological context (Rieau, 2014; Alagich et al., 2018).

Another crucial aspect of animal husbandry is animal mobility. Zooarchaeological analyses (e.g., mortality profiles, butchery marks on bones, and anatomical and taxonomic representation) suggest that the livestock was raised locally (e.g., Gardeisen, 2010; Forest, 2013; Albesso et al., 2013).

Strontium isotope ratio analysis is a well-established method for assessing livestock mobility. The first strontium ratios obtained from two Iron Age sites located close to the coast of the Languedoc region (La Monédière and *Lattara*) showed that the caprines and cattle consumed at these sites were mainly reared locally (Nieto-Espinet et al., 2020). These results suggest the presence of local livestock breeding and limited animal mobility in coastal sites during the Iron Age. A wide number of zooarchaeological studies in Languedoc attest to the fact that sheep, goats and cattle were smaller compared to animals dated from earlier and later times in this region (e.g., Forest and Rodet-Belarbi, 2002; Boulbes and Gardeisen, 2014, 2018; Duval and Clavel, 2018; Nieto-Espinet et al., 2020). This size reduction could have been the result of a combination of several factors, including human demographic increase, the expansion of cultivated fields, territorialisation, reduced livestock movement, and pressure on grazing areas, as previously suggested (Duval et al., 2012; Valenzuela-Lamas and Albarella 2017; Trentacoste et al., 2018, 2021; Nieto-Espinet et al., 2021a, 2021b). Other hypotheses include environmental factors (e.g., Davis, 1981), the easier manageability of smaller animals (Clutton-Brock, 1981), and increased reproductive pressure (Manning et al., 2015).

While animal mobility patterns in the coastal areas are known (Nieto-Espinet et al., 2020), this aspect has yet to be investigated in the hinterlands of Languedoc. Transhumance is a phenomenon that has been documented since the Middle Ages in the Cévennes mountains (south-eastern fragment of the Massif Central) (e.g., Brechon, 2019), and it still occurs today (e.g., Cleary, 2017) (Fig. 1). Indeed, some authors have even suggested that this type of livestock management approach could have been taking place in Iron Age times (e.g., Gascó, 2001). Thus, strontium isotope analyses of Iron Age sites located in the hinterland of the Languedoc region could shed new light on this issue.

This paper aims to characterise (1) the strategies used by herders to feed cattle and caprines in the coastal and inland areas, and thus to assess the differences and similarities between species and geographical zones. In addition, (2) we analysed animal mobility in the hinterland of the Iron Age Languedoc region. The results obtained were compared to a previous study on caprine and cattle teeth from coastal sites (Nieto-Espinet et al., 2020), to analyse the variability between the coastal and inland areas. To do that, we combined zooarchaeology, dental mesowear, dental microwear and isotope analyses –strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O$), and carbon ($\delta^{13}C$)– in caprines and bovines from five major Iron Age sites in Languedoc: Cayla de Mailhac, la Monédière, la Ramasse, le Cailar and *Lattara*. This is the first time a multiproxy approach of this kind has been combined into a single work on domestic ungulates. The preliminary results provide new insights into livestock management strategies in Iron Age Languedoc and help to elucidate the socio-political context at that time.

2. Materials and methods

2.1. Archaeological sites

Five archaeological sites from Languedoc region (southern France) were selected for several reasons. Firstly, they provide good bone preservation and a reliable chronology. Secondly, in order to analyse the variability between the inland and the coastal areas, we selected three major sites located near to the coast: le Cailar, la Monédière and *Lattara*; and two major sites located in the inland areas: Cayla de Mailhac and la Ramasse (Fig. 1).

Table 1
Number of samples analysed per archaeological site, chronological period and proxy.

Proxy	Zooarchaeological site								Total
	Lattara		La Monédière		Le Cailar		Cayla de Mailhac	La Ramasse	
Chonological period	6th-5th BC	5th-4th BC	6th-5th BC	5th-4th BC	6th-5th BC	5th-4th BC	5th-4th BC	5th-4th BC	
Zooarchaeology (NISP)	1303	4466	(Beylier et al., 2018;Nieto-Espinet et al., 2020)		Py et al., 2002; Creuzieux, 2009)		664	227	6660
Dental mesowear	21	8	33	21	6	44	8	34	175
Dental microwear	39	21	42	23	5	60	13	55	258
Strontium isotope	–		–		–		6 (samples = 18)	3 (samples = 9)	9 (27)
Oxygen isotope	–		–		–		6 (samples = 30)	3 (samples = 12)	9 (42)

2.1.1. *Lattara*

Lattara (Lattes, Hérault) is an Iron Age site located on the shores of a lagoon in the Lez Delta that was occupied from the 6th century BC to the 3rd century AD (Py and Garcia, 1993; Gailledrat, 2014; Gailledrat and Vacheret, 2020). Founded ca. 500 BC, two residential areas (zone 1 and zone 27) located inside the fortified city have provided evidence of the earliest chronological phases of this site. The architecture and material recovered suggest an Etruscan settlement during this first occupation (Py, 1993, 1995; Gailledrat and Vacheret, 2020). The faunal assemblage studied comes from zone 1, located in the north-eastern sector of the site. Two chronological periods have been analysed: Phase 1T/1S (500–475 BC) and Phase 1P/1R (475–425 BC).

2.1.2. *La Monédière*

La Monédière (Bessan, Hérault) is an archaeological site located near the mouth of the Hérault river, about 6 km from the present-day coastline. The settlement, whose area is estimated at about 4.5 ha, was mainly occupied between the beginnings of the 6th century and the end of the 5th century BC. The archaeological findings identified in this fortified city reveal the importance of Mediterranean influence on the culture and architecture at the site. In addition, this site could have had a redistribution function between indigenous and Mediterranean cultures (e.g., Greek and Etruscan) (Nickels, 1983; Gailledrat, 2014; Beylier et al., 2018). The faunal assemblage studied dates from 575 to 425 BC (Beylier et al., 2018; Nieto-Espinet et al., 2020).

2.1.3. *Le Cailar*

The Iron Age settlement of Le Cailar (Le Cailar, Gard), occupied since the 6th century BC, was located on the edge of an ancient lagoon in the lower Rhône valley (Py et al., 2002; Roure et al., 2011). The large number of imported goods (in particular massailotte amphorae) along with certain architectural elements of this fortified city suggest that Le Cailar was a significant trading post in the Mediterranean. The faunal samples come from layers dated between the 5th and 4th centuries BC (Gardeisen, 2002; Creuzieux, 2009).

2.1.4. *La Ramasse*

La Ramasse (Clermont-l'Hérault, Hérault) is an Iron Age *oppidum* (5 ha) perched on a small hill (257 m a.s.l.) in the Hérault river valley. More specifically, it is located on one of the first southern foothills of the Massif Central range. The settlement, occupied from 530 BC to 400 AD, is 30 km north of La Monédière and 45 km northwest of *Lattara* (Garcia, 1992, 1993). The archaeological excavations focused on a residential area located on the north-western side of the site. The faunal remains studied come from the Dwelling 6 and 7 units, dated between 450 and 325 BC.

2.1.5. *Cayla de Mailhac*

The Cayla de Mailhac *oppidum* (Mailhac, Aude) is located on a steep hill (144 m a.s.l.), which is one of the first reliefs of the Massif Central (Taffanel et al., 1998; Gailledrat, 1997b, Gailledrat et al., 2002; Beylier and Gailledrat, 2009). The archaeological excavations conducted in 1993 were carried out on the southern edge of one of the former excavations (1934–1937). This archaeological survey offered a complete stratigraphic sequence of the phases Cayla II (575–475/450 BC) and Cayla III (475/450–325 BC) (Gailledrat, 1997b). This work enabled the identification of some domestic dwellings and several post marks. The faunal remains come from this archaeological survey.

2.2. *The samples*

We employed a multiproxy approach (zooarchaeology, meso- and microwear analyses, as well as isotope analyses of oxygen, carbon and strontium) to samples from five archaeological sites. The number of samples per site and analysis type is presented in Table 1.

The zooarchaeological analyses in this paper include previously unpublished material: *Lattara*, NISP = 5759; La Ramasse, NISP = 227; and Cayla de Mailhac NISP = 664. The faunal assemblages from La Monédière (Beylier et al., 2018; Nieto-Espinet et al., 2020) and Le Cailar (Py et al., 2002; Creuzieux, 2009) have been analysed in previous studies. A total of 268 teeth were selected for microwear analysis (Table 1). Because of the absence of significant differences between teeth from the same tooth row in low-magnification dental microwear analysis (Rieau, 2014; Xafis et al., 2017), we selected the first (M1), second (M2) and third (M3) lower and upper molars identified as adult sheep (*Ovis aries*), goats (*Capra hircus*), and cattle (*Bos taurus*). Adult individuals were favoured in the selection to avoid age structure discrepancies (Rivals et al., 2007). A total of 175 teeth were available for the dental mesowear analysis (Table 1); lower and upper M1, M2 and M3 molars of adult sheep, goats, and cattle were selected (Fortelius and Solounias, 2000; Franz-Odendaal and Kaiser, 2003; Kaiser and Solounias, 2003; Rivals et al., 2007; Blondel et al., 2010). For the isotope analyses, a sequential sampling of enamel along the tooth crown was carried out on six caprines (including two sheep and one goat) from Cayla de Mailhac, and three caprines (including two sheep) from La Ramasse. We also analysed the strontium isotope ratio in the (cortical) bone of two rabbits (*Oryctolagus cuniculus*) from Cayla de Mailhac and a red deer (*Cervus elaphus*) from La Ramasse to obtain the local isotope ratio of these sites, as bones equilibrate their $^{87}Sr/^{86}Sr$ ratios with that of the burial environment (e.g., Price et al. 2002; Lee-Thorp and Sponheimer 2003). A total of 30 samples were taken for strontium ($^{87}Sr/^{86}Sr$) analysis, as well as 42 for oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope analyses (Table 1).

2.3. *Zooarchaeological analysis*

The zooarchaeological analysis included anatomical and taxonomic identification, in addition to determining the laterality, portion, face, and age at death (Grant, 1982; Payne, 1973; Gardeisen, 1997; Helmer, 2000). Whenever possible, sheep and goats were distinguished following the criteria of Halstead et al. (2002) and Helmer (2000). When this was not possible, they were assigned to the subfamily of caprines (Caprinae). When taxa could not be identified, the faunal remains were classified according to the animal's body size, taking into account the

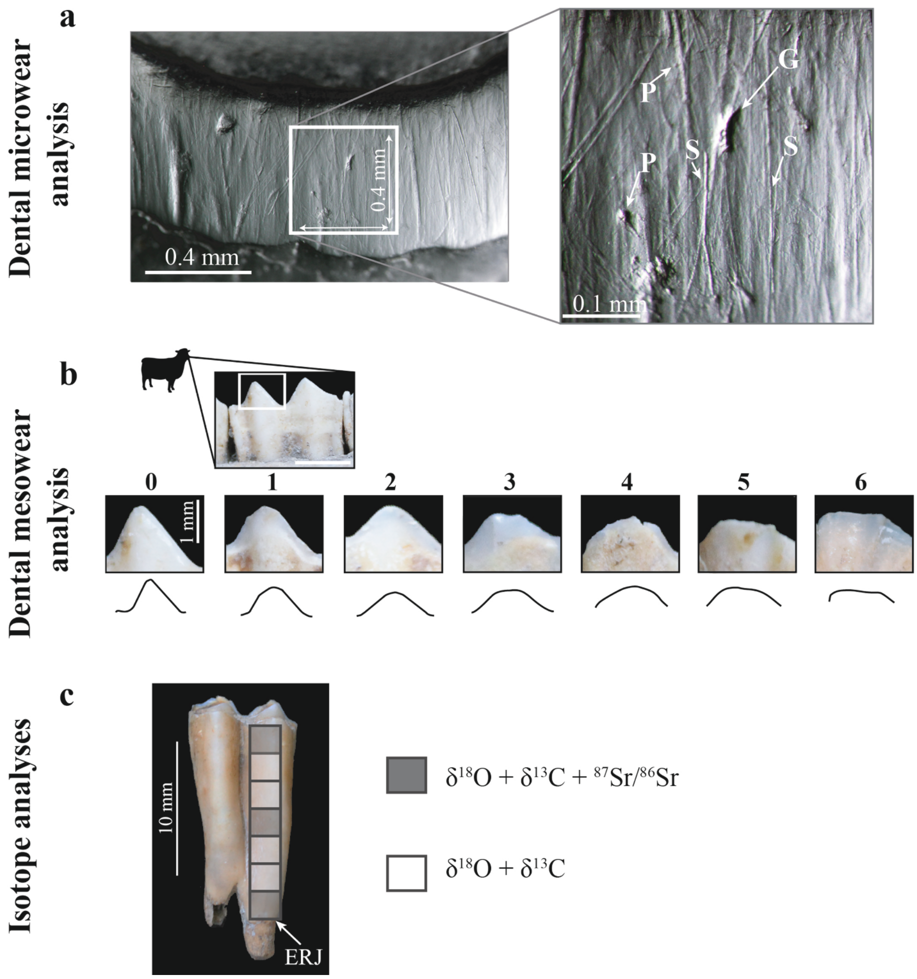

Fig. 2. Proxies used in this study: A) Image (x35) of the dental microwear surface and the features identified: pits (p), scratches (s) and gouges (G); B) The scale used to the analysis of the mesowear score (MWS); C) Sampling of stable isotopes of oxygen, carbon and strontium.

faunal spectrum of the assemblages and their age: large (<150 kg), medium sized (15–100 kg), and small (<15 kg). The integrity of the assemblage was based on the Number of Identified Specimens (NISP) and the Minimum Number of Individuals combination (MNIc) (Lyman, 1994). The mortality profiles were obtained using the Bayesian method developed by Valenzuela-Lamas and Pozo-Soler (2011). This technique consists of producing mortality profiles (histograms) and survival curves using the Bayesian method, which takes into account the data obtained on both the degree of fusion of the bones and dental elements. These were interpreted according to the zootechnical models of animal production strategies described by several authors (e.g., Payne, 1973; Stein, 1987; Helmer and Vigne, 2004; Helmer et al., 2005, 2007; Blaise, 2005, 2009).

2.4. Dental microwear analysis

Dental microwear was analysed following the method proposed by Solounias and Semprebon (2002). The occlusal surface of each tooth was carefully cleaned using acetone and then with 96% ethanol (Semprebon et al., 2004). The occlusal surface was then moulded using the high-precision polyvinylsiloxane dental impression material Provil Novo Light C.D.2 (Heraeus Kulzer) for the first contact layer, followed by Blue Eco Putty (Detax) for the support layer. Epoxy resin (C.P Química CPOX P 1069/A – CPEN 1585/B) was used to make transparent casts from these moulds. The epoxy casts were analysed using a Leica MZ16 stereomicroscope at low magnification (x35), at the CNRS-UMR 5140 laboratory (Montpellier, France). For each tooth, we analysed two different areas of 0.4 mm × 0.4 mm (0.16 mm^2) and averaged the data from the protoconid and/or hypoconid of the first (M1), second (M2), and third (M3) lower molars, as well as for the paracone and/or metacone of the upper M1, M2, and/or M3 (Rieau, 2014; Xafis et al., 2017). The low magnification observation avoided the recording of taphonomical alterations such as fissures and damaged areas (King et al., 1999; El-Zaatari, 2010; Uzunidis et al., 2021). The microwear observation was performed by a single experienced observer (SJM) (Mihlbachler et al., 2011; Semprebon and Rivals, 2007). Five microwear variables were recorded: the number of pits (NP), the number of scratches (NS), the presence/absence of gouges (G), the scratch width score (SWS), and the presence/absence of cross scratches (XS). Pits are features with an oval or circular morphology (uniform width and length) (Fig. 2a), and scratches are features that are longer than they are wide (Fig. 2a). Gouges are depressions with irregular limits which are wider (2–3 times) and deeper than pits. The predominant scratch width (SWS) was scored qualitatively: ‘0′ indicates the predominance of fine scratches; ‘2′ the predominance of coarse scratches; and ‘1′ intermediate width scratches. Fine scratches are narrower than coarse scratches. In addition, under illumination, fine scratches have low refractivity. The absence or presence of more than four scratches (XS) was also registered (Solounias and Semprebon, 2002).

The number of pits and scratches is used to discriminate between grazer, browser and mixed dietary regimes in ruminants (Hofmann, 1989; Solounias and Semprebon, 2002; Semprebon et al., 2004). Due to the high content of phytoliths in grasses, grazers present a higher number of scratches (more than 17), browse feeders have a higher

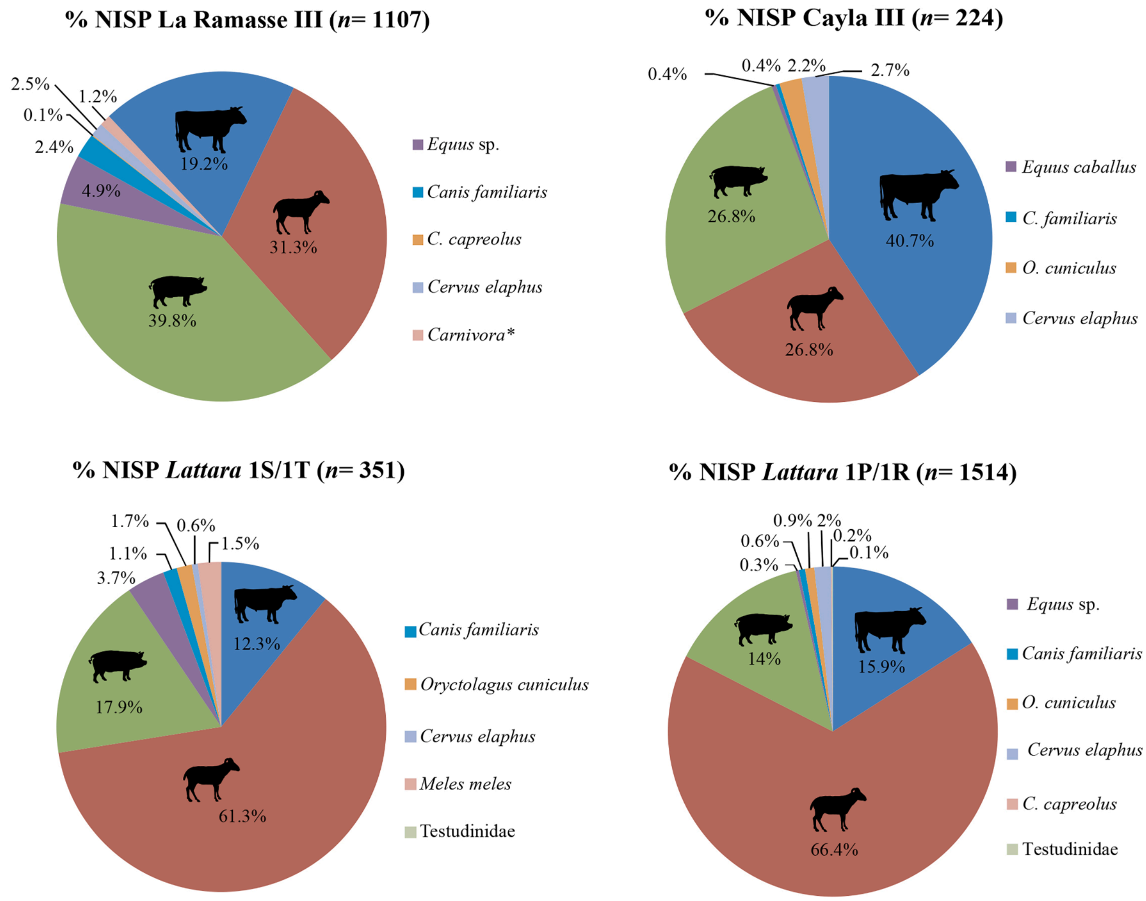

Fig. 3. Percentage of the number of identified specimens (%NISP) of La Ramasse III (450–325 BC), Cayla de Mailhac III (450–325 BC), *Lattara* 1S/1T (500–475 BC) and *Lattara* 1P/1R (475–425 BC) (*carnivora** includes *Meles meles, Vulpes* sp., *Felis* sp., and undetermined carnivores).

number of pits and fewer scratches (<17), while mixed feeders present a variable number of scratches and pits (Solounias and Semprebon, 2002). Pits and scratches can also be produced by external particles such as dust and grit (e.g., Merceron et al., 2016; Gallego et al., 2020; Schulz-Kornas et al., 2020). An exploratory biplot graph using the total number of scratches and pits was developed using the R Statistical Software package (version 3.5.1) and R code from Rivals (2019). Sheep and goats were grouped when there were fewer than three specimens. Further, after verifying the normality of variables, a one-way ANOVA test was run to evaluate significant differences between taxa and geographical areas (p-value threshold = 0.05). The statistical procedure was carried out using IBM SPPS statistics software.

2.5. Dental mesowear analysis

Dental mesowear is a technique based on an analysis of the differences in the morphology of dental cusps caused by food items during mastication (Fortelius and Solounias, 2000; Lucas, 2004). The technique employed was the MesoWear Score (MWS). This consists of the macroscopic and qualitative analysis of dental cusps located on the buccal side of upper molars and the lingual side of lower molars (Fortelius and Solounias, 2000; Franz-Odendaal and Kaiser, 2003; Kaiser and Solounias, 2003; Blondel et al., 2010). Cusps are classified into seven categories, where ’0′ are high-relief pointed cusps, corresponding to the least abrasive wear, and ’6′ are low-relief flattened (blunt) cusps, corresponding to the most abrasive wear (Fig. 2b) (Rivals et al., 2007; Mihlbachler et al., 2011). Browser dietary regimes vary between MWS values of 0 to 2.00; grazer regimes between 2.09 and 5.47; and mixed feeders between 0.40 and 2.74 (Fortelius and Solounias, 2000; Rivals et al., 2007; Mihlbachler et al., 2011). The presence of significant differences between species was tested with an analysis of variance (ANOVA) run using IBM SPPS statistics software.

2.6. Oxygen, carbon and strontium isotope analyses

A total of nine caprine teeth were sampled for strontium, oxygen and carbon isotope analyses. The caprine teeth included eight first lower molars and one second lower molar. This selection was made due to the absence of second and third molars in the zooarchaeological record. The mineralisation of first molars starts *in utero*, in the months prior to birth, and it is completed during the first months of life; the mineralisation of second molars occurs during the first year of life (Fricke and O’Neil, 1996; Hillson, 2005). Consequently, these reflect different moments in the life of the individuals.

Sequential sampling was performed along each tooth crown to assess the timing and seasonality of enamel mineralisation, as well as possible changes in grazing areas during tooth formation. Firstly, the enamel surface was mechanically cleaned with a burr coupled to a rotary micromotor. Secondly, transverse slices of c. 2 mm from the buccal side of the second pillar of each tooth were cut using a diamond rotary saw. Finally, dentine was mechanically removed with a burr coupled to a rotary micromotor (Fig. 2c).

Three slices (one from the top, one from the middle, and one from the bottom) were selected for strontium, carbon and oxygen isotope analyses. In addition, whenever possible, two more slices from other locations on the tooth crown were selected for oxygen and carbon isotope analyses. Consequently, whenever possible, a maximum of five samples for oxygen/carbon and three samples for strontium were selected from each tooth.

The slices devoted to strontium isotope analyses were transferred to

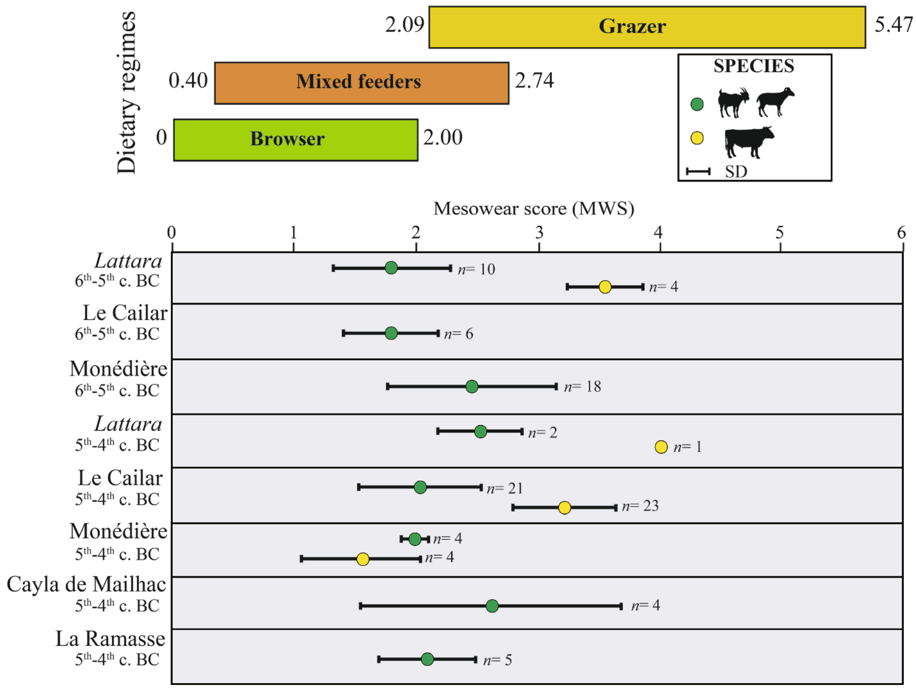

Fig. 4. Dental mesowear results of cattle and caprines and dietary bars of extant ungulates (Fortelius and Solounias, 2000). The mean (point) and the standard deviation (bar) are presented (n = number of samples).

the laboratory at Géosciences Montpellier (University of Montpellier–CNRS, France) for further cleaning and chemical processing following standard procedures (Pin et al., 1994, see Valenzuela-Lamas et al., 2018, for details). The isotope ratios were measured using a Neptune + Thermo Scientific Multi-Collector Inductively-Coupled-Plasma Mass Spectrometer (MC-ICP-MS) from the AETE-ISO platform (OSU OREME) at the University of Montpellier. Total chemistry blanks were <20 pg and, thus, negligible for this study. The samples were alternatively run with international NBS 987 standards using a sample-standard-bracketing measurement protocol wherein standards were run every 3 unknowns. The ^{88}Sr beam intensity for all standards and samples ranged from 8 V to 15 V. ^{87}Sr/^{86}Sr isotope ratios were corrected for mass fractionation using an exponential mass bias law and a ^{86}Sr/^{88}Sr ratio of 0.1194. The corrected isotope ratios were then normalised to the NBS 987 standards, which gave a mean value of 0.710245 with a reproducibility of ±0.000005 (2 s, n = 10) during the course of this study. The enamel samples devoted to oxygen and carbon isotope analysis were crushed in an agate mortar and sent in individual pre-weighed Eppendorf tubes for further analysis in the AETE-ISO laboratory at the OSU OREME, University of Montpellier. The oxygen and carbon isotope composition of the carbonate fraction of the apatite was measured using a Thermo Delta V + IRMS coupled to a Kiel device. CO_2 was released from the sample through reaction with 105% orthophosphoric acid, and measured against a reference gas. The international isotope reference materials IAEA-603 and NBS-18 were used to perform the calibration, and the values were given as δ^{13}C and δ^{18}O on the VPDB scale. Duplicates were analysed to assess the reproducibility of ±0.08‰, and the overall precision of ±0.30‰. R version 4.0.5 and the 'car', 'ggplot2', 'ggrepel', 'lattice', 'readxl' and 'stats' packages together with the development package 'zoowork' were used to visualise the isotope data (Fox 2007; Wickham 2011; Slowikowski et al., 2018; Sarkar et al., 2015; Wickham et al., 2019; Huet et al., 2022). The lines uniting the dots in the carbon and oxygen results were calculated using the 'spline' function ('natural' method) in the R package 'stats'.

3. Results

3.1. Zooarchaeological analysis

At the *Lattara* site (Phase 1 T/1S), 26.9% of the faunal remains were anatomically and taxonomically determined. The rest were classified either according to size or as unidentified (Supplementary Material 1). Among the identified samples, the majority corresponded to caprines (NISP = 61.3%), followed by pigs (NISP = 17.9%), and cattle (NISP = 12.3%). Sheep (NISP = 14; MNIc = 6) are better represented than goats (NISP = 4; MNIc = 3) (Fig. 3). The caprine mortality profile shows a slaughter peak for juvenile (6–12 month) and adult (12–24 month) individuals. This reflects meat (type A) and milk (type B) exploitation (Supplementary Material 2). The cattle were mainly slaughtered between 12 and 24 months (meat type B) and 24–48 months (milk type B) (Helmer and Vigne, 2004; Helmer et al., 2007). In the subsequent phase (*Lattara* 1P/1R), 33.9% of the faunal remains were identified. As in the previous phase, caprines are the most well-represented taxon (NISP = 66.4%), where sheep (NISP = 84; MNIc = 21) predominate over goats (NISP = 45; MNIc = 11). Cattle are the second most-frequent taxon (NISP = 15.9%), and pigs the third (NISP = 13.8%) (Fig. 3 and Supplementary Material 3). The mortality profile of caprines shows that the majority of individuals were slaughtered before they reached 24 months. This is compatible with the exploitation of tender meat (type B). The slaughter of very young individuals (<6 months) is also compatible with the exploitation of milk (Helmer and Vigne, 2004; Helmer et al., 2007). The cattle profile shows that about half of the individuals were slaughtered from 12 to 24 and 24–48 months (Supplementary Material 2). This indicates their exploitation for meat (Blaise, 2009). The other half were slaughtered up to 8 years of age, probably due to their use for milk production and/or traction.

At the La Ramasse site (phase III), 66.1% of the faunal remains were identified. Caprines were the most abundant (NISP = 46%), followed by pigs (NISP = 32%), and then cattle (13.3%) (Supplementary Material 4). Goats (NISP = 8; MNIc = 3) were more abundant than sheep (NISP = 5; MNIc = 2) (Fig. 3). The mortality profile of caprines indicates that sheep and goats were mainly slaughtered between 24 and 48 months and

Table 2
Results from Mesowear Score (MWS) analysis of caprines and cattle (*n* = number; SD = standard deviation).

Archaeological site	Caprines			Cattle		
	n	MWS	SD	*n*	MWS	SD
Lattara 6th-5th c. BC	10	1.8	0.91	4	3.5	0.58
Le Cailar 6th-5th c. BC	6	1.7	0.93	–	–	–
La Monédière 6th-5th c. BC	18	2.2	1.25	–	–	–
Lattara 5th-4th c. BC	2	2.5	1	1	4	–
Le Cailar 5th-4th c. BC	21	1.81	1.14	23	3.2	0.99
La Monédière 5th-4th c. BC	4	2	0	4	1.75	0.96
La Ramasse 5th-4th c. BC	5	2	0.7	–	–	–
Cayla de Mailac 5th-4th c. BC	4	2.5	2.05	–	–	–

48–72 months (Supplementary Material 5). This suggests the exploitation of milk (type B) and wool. The cattle profile has not been analysed because of the low number of specimens.

At Cayla de Mailhac, phase II/III provided a very low number of identified specimens (NISP = 21). In the subsequent phase (Cayla IV/V), 36.8% of the faunal remains were anatomically and taxonomically identified. Cattle (NISP = 41.1%) are the most well-represented, followed by caprines (NISP = 26.8%), and then pigs (NISP = 26.3%) (Supplementary Material 6). The distinction between sheep and goats was possible for seven specimens: two correspond to sheep (MNIc = 2) and five to goats (MNIc = 2) (Fig. 3). The caprine mortality profile evidences their exploitation for meat (type B) with a peak of individuals slaughtered from 12 to 24 months. The exploitation of caprines older than 24 months suggests milk (type B) and wool production. The cattle were slaughtered before they reached 48 months of age, probably for the exploitation of meat (Supplementary Material 5). The other individuals (i.e., those older than 48 months) could have been used for milk production or agricultural work.

3.2. Dental mesowear pattern

The overall results obtained from the dental mesowear analysis of the archaeological samples are presented in Fig. 4 and Table 2. Goats (*Capra hircus*) and sheep (*Ovis aries*) are grouped into the category 'caprines'

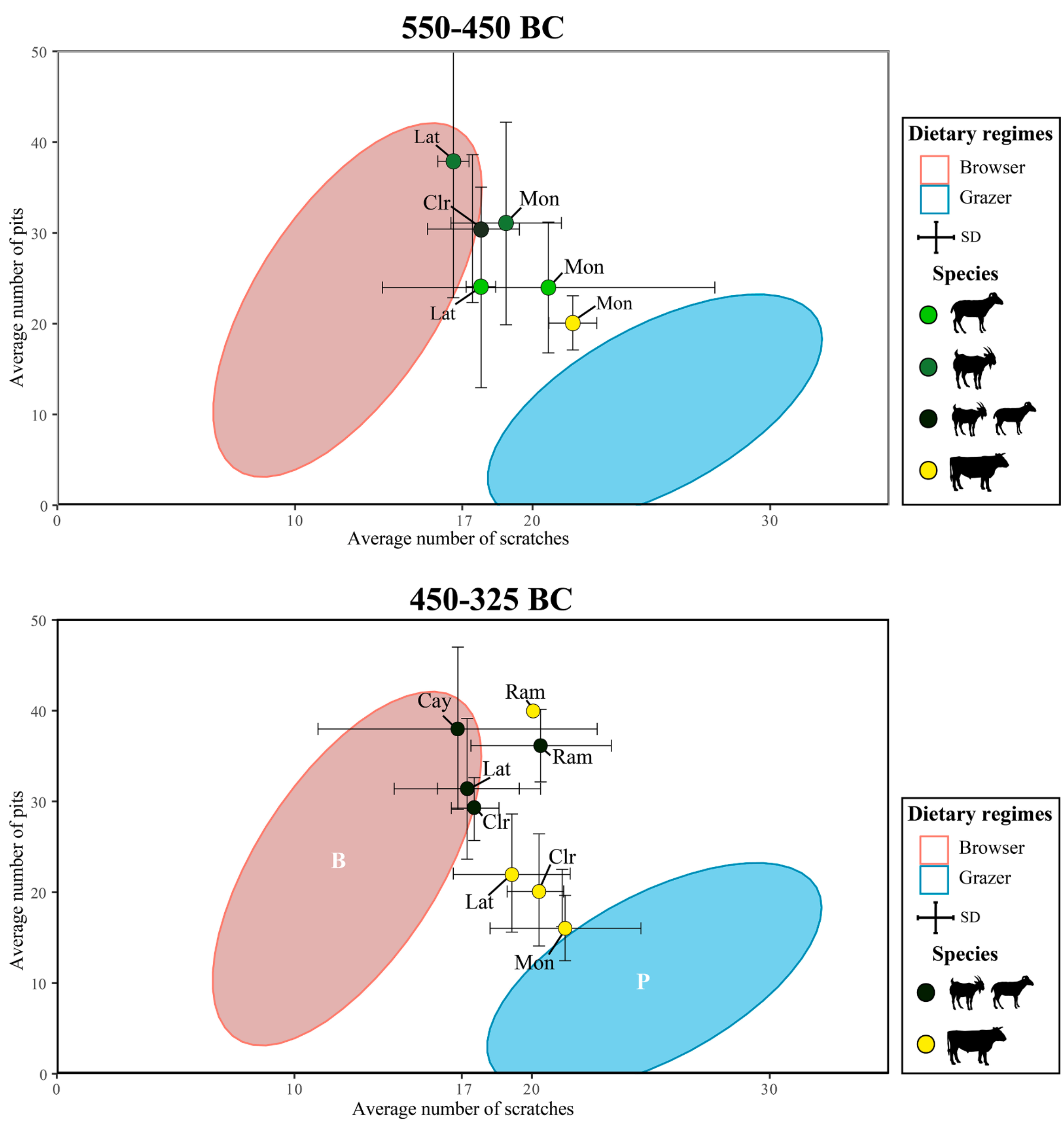

Fig. 5. Dental microwear results of cattle, sheep, goat and undetermined caprines by chronological phase and archaeological site. The mean (point) and the standard deviation (bar) are presented. The ellipses indicate leaf browswer (B) and grazer (G) from Solounias and Semprebon.

Table 3
Summary of microwear patterns of cattle, indetermined caprines, sheep and goats (N = number, NP = number of pits; DSM = deviation standard of the mean; NS = number of scratches; SWS = scratch width score; XS = presence of more than four cross scratches; G = presence of gouges).

Archaeological site	Cattle								Caprinae								Sheep								Goat							
	N	NP	DSM	NS	DSM	SWS	XS	G	N	NP	DSM	NS	DSM	SWS	XS	G	N	NP	DSM	NS	DSM	SWS	XS	G	N	NP	DSM	NS	DSM	SWS	XS	G
***Lattara* 6th-5th c. BC**	–	–	–	–	–	–	–	–	14	34.1	11.9	14.4	3.6	0.5	0.2	0	4	24.3	5.5	17.6	0.3	0.25	0.25	0	3	37.6	8.2	16.6	0.3	0.25	0	0
Le Cailar 6th-5th c. BC	–	–	–	–	–	–	–	–	4	30.3	8.6	17.5	2	0.25	0.25	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
La Monédière 6th-5th c. BC	19	19.3	4.3	20.8	1.8	1.1	0.7	0	2	20	8.5	23	8.5	1	0.5	0	3	24.3	6.8	20.3	6.1	1	0.3	0	5	30.8	12.3	18.9	2.6	1.25	0.4	0
***Lattara* 5th-4th c. BC**	4	21.6	13.1	19.1	4	0.5	0.75	0	5	32.4	12.9	18	5.4	0.4	0.25	0	6	27.1	9.6	16.3	3.8	0.5	0.2	0	1	41	–	14	–	0	0	0
Le Cailar 5th-4th c. BC	37	19.9	6.9	15.9	4.3	0.4	0.5	0.1	7	31.3	11.1	17.5	2.4	0.9	0.1	0	15	28	7	17.2	2	0.4	0.1	0.1	–	–	–	–	–	–	–	–
La Monédière 5th-4th c. BC	6	15.9	4.4	21.3	4.2	0.7	0.8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
La Ramasse 5th-4th c. BC	–	–	–	–	–	–	–	–	2	35.5	9.2	16	5.7	1	0.5	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cayla de Mailac 5th-4th c. BC	1	40	–	20	–	1	0	0	4	34.6	12.3	20.9	8.5	1	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(Caprinae) due to the low number of teeth specifically identified. Of the 175 available teeth, 73 were discarded because the cusps were broken or damaged. The mesowear scores (MWS) for caprines (550–450 BC and 450–325 BC) range from 1.8 at *Lattara* (550–450 BC) to 2.5 at Cayla de Mailhac (550–450 BC) and *Lattara* (550–450 BC) (see Fig. 4 and Table 2 for more details per site and chronological phase). These values indicate dietary patterns typical of mixed feeders (Fortelius and Solounias, 2000; Mihlbachler et al., 2011). The cattle (*Bos taurus*) show a higher MWS than the caprines: from 3.2 at Le Cailar (5th-4th centuries BC) to 4 at *Lattara* (5th-4th centuries BC), with the exception of the La Monédière site (MWS = 1.75). Taking into account the low number of samples from La Monédière ($n = 4$), this would indicate a less abrasive dietary regime at this site. In general, this data suggests that the resources consumed by cattle were more abrasive and, consequently, a grazer-type diet. The one-way ANOVA test shows highly significant differences between caprines and cattle (Sum of sqrs = 24.7; df = 1; F = 20.8; p value ≤ 0.001).

3.3. *Dental microwear pattern*

A total of 142 teeth from goats, sheep and cattle were analysed after discarding enamel surfaces with taphonomic alterations (Rivals et al., 2007; King et al., 1999; El-Zaatari, 2010; Uzunidis et al., 2021). The results are summarised in Fig. 5 and Table 3.

In the first chronological period (550–450 BC), the sites of *Lattara*, La Monédière and Le Cailar yielded results. The microwear pattern for the goats is characterised by a high number of pits (30.8 ≤ Mean ≥ 41) and an intermediate number of scratches (14 ≤ Mean ≥ 18.9). These results indicate a browsing-dominated mixed-feeding diet. The high number of pits could be related to the intake of woody plants and/or grit present on the leaves or fodder. Animals can also consume grit and/or dust when they are feeding on plants near the ground (Solounias and Semprebon, 2002; Rieau, 2014; Gallego et al., 2020). The enamel surfaces on the sheep teeth presented a lower number of pits than those of the goats (24.3 ≤ Mean ≥ 28) and an intermediate number of scratches (16.3 ≤ Mean ≥ 20.3). These results suggest a grass-dominated mixed-feeding diet (Solounias and Semprebon, 2002). The diet of the cattle was only analysed at the La Monédière site. The cattle present a high number of scratches (Mean = 20.8) and a low number of pits (Mean = 19.3). These values plot close to the confidence ellipse for modern grazers (Solounias and Semprebon, 2002) (Fig. 5).

The five archaeological sites provided samples for the second chronological period (450–325 BC). Sheep and goats are grouped as caprines. Caprines from inland sites (Cayla de Mailhac and La Ramasse) present a high number of pits (34.6 ≤ Mean ≥ 35.5) and an intermediate number of scratches (16 ≤ Mean ≥ 20.9). The microwear pattern for the small ruminants from sites located near to the coast (*Lattara* and le Cailar) features a lower number of pits (31.4 ≤ Mean ≥ 32.4) and an intermediate number of scratches (17.5 ≤ Mean ≥ 18) than the sites located in inland areas. The one-way ANOVA test, performed to evaluate significant differences between caprines from inland sites and those near the coast, shows the absence of significant differences (Pits: Sum of sqrs = 133.8; df = 1; F = 1.4; p value = 0.24; Scratches: Sum of sqrs = 44.7; df = 1; F = 3.4; p value = 0.07). The microwear pattern of cattle from sites located near to the coast is characterised by a low number of pits (15.9 ≤ Mean ≥ 21.6) and an intermediate to high number of scratches (15.9 ≤ Mean ≥ 21.3). These results suggest a grass-dominated mixed-feeding diet for the cattle. Only one cattle tooth was available from the inland sites. Its values (no. pits = 40, no. scratches = 20) could indicate a high intake of dust and/or grit (Solounias and Semprebon, 2002). A one-way ANOVA test was conducted to evaluate the presence of significant differences between caprines and cattle. The results show the presence of highly significant differences (Pits: Sum of sqrs = 2448.6; df = 1; F = 34.3; p value ≤ 0.001; Scratches: Sum of sqrs = 295.1; df = 1; F = 18.1; p value ≤ 0.001).

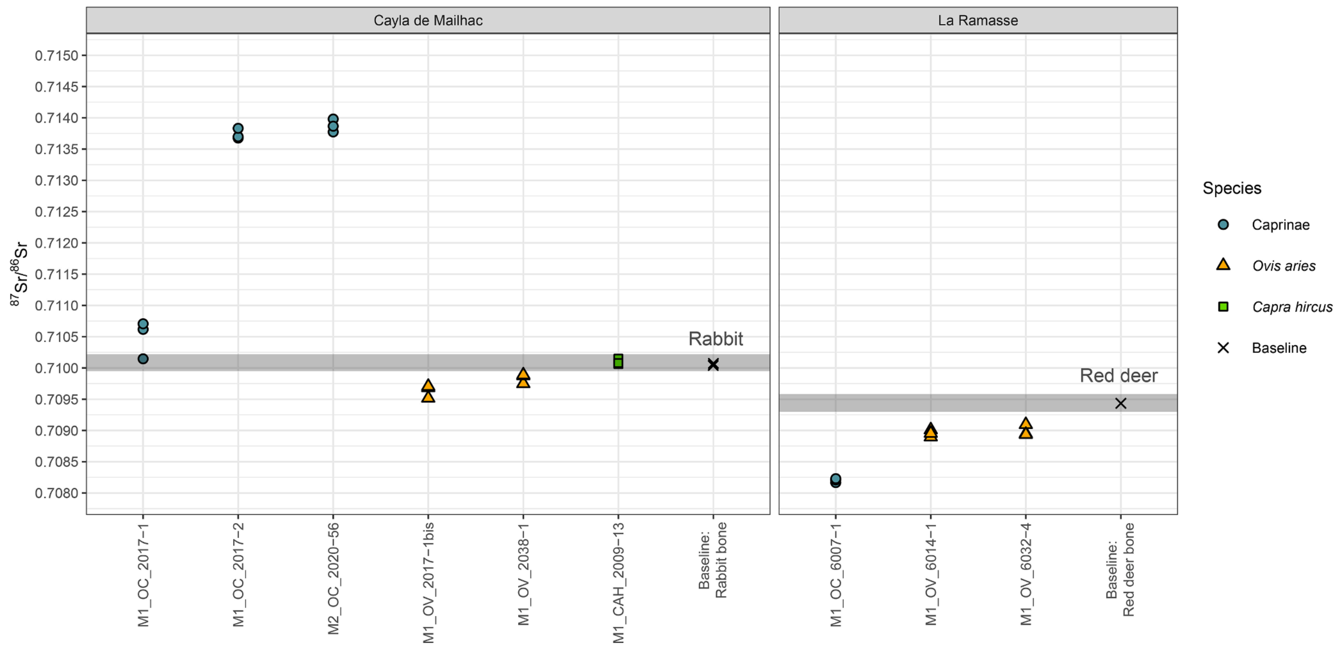

Fig. 6. Strontium isotopic ratios ($^{87}Sr/^{86}Sr$) obtained from archaeological sheep (OV), goat (CAH) and caprine (OC) enamel from Cayla de Mailhac and La Ramasse. Baseline samples are obtained from rabbit and red deer cortical bone. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.4. $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and isotope analyses

Fig. 6 shows the strontium isotope ratio for each tooth. The local baseline obtained by sampling wild animal bones is also presented for each archaeological site. The values obtained at Cayla de Mailhac range from 0.7095 to 0.7108 in four teeth (2009–13, 2038–1, 2017–1, 2017-1bis) (Supplementary Material 7). The strontium isotope ratios of those four individuals are compatible with the Sr isotopic signature from the Cenozoic sediment found in neighbouring areas of the archaeological site (according to Voerkelius et al., 2010; Willmes et al., 2018) (Figs. 6 and 7. In addition, these values are consistent with the local baseline (between 0.7099 and 0.7100) obtained from the analysis of two rabbit bones (*Oryctolagus cuniculus*) recovered from the site (Supplementary Material 7 and Fig. 6).

From Fig. 6, it is clear that two caprines (2020–56 and 2017–2) present distinct results. These specimens yielded isotopic strontium ratios ranging between 0.7136 and 0.7140. These values may be compatible with Lower Palaeozoic (Cambrian to Ordovician) sediments (Voerkelius et al., 2010; Willmes et al., 2018) like those from the Caroux-Espinouse massif, which is part of the Massif Central (Fig. 7) and located 15 km from the sampled site (Fig. 7).

The strontium isotope ratios obtained at La Ramasse range between 0.7089 and 0.7090 in two of the three caprines (6014-1 and 6032-4). These ratios are compatible with the local strontium isotope ratio obtained by sampling a red deer bone (*Cervus elaphus*) recovered from the site (0.7094) (Fig. 6 and Supplementary Material 7). A number of studies attest to similar strontium isotope ratios in the Mesozoic sediments that surround the sampled site (e.g., Evans et al., 2010; Voerkelius et al., 2010; Valenzuela-Lamas et al., 2018; Willmes et al., 2018; Snoeck et al., 2020). A third specimen (6007-1) presents significantly lower values (0.7079–0.7082). These values are not compatible with the local signal and they differ greatly from the other two individuals studied.

Fig. 8 displays the sequential oxygen curves and the strontium isotope ratios (measured from the enamel root junction (ERJ), expressed in mm). Overall, the oxygen values range between −4.74 and 1.93. The intra-tooth $\delta^{18}O$ sequences for M1 and M2 reflect the seasonal cycle during the period of tooth formation. The lowest values are related to the cold season, and the highest values are related to the warm season. In all the teeth, apart from 2017-1 (Cayla de Mailhac) and 6007-1 (La Ramasse), the strontium isotope ratio presents similar values throughout the period of tooth growth. These results suggest the absence of mobility between geologically distinct areas during the period of tooth formation in six of the eight specimens analysed.

Fig. 9 plots the average results obtained for the $\delta^{18}O$ and $\delta^{13}C$ isotopes (Supplementary Material 7). For all first molars, $\delta^{13}C$ averaged values vary between 13.2‰ and −10.9‰, and the $\delta^{18}O$ values vary between −1.6‰ and 0.25‰. For the only M2 sampled, the averaged values are −3.3‰ ($\delta^{18}O$) and −12.6‰ ($\delta^{13}C$).

Fig. 10 presents a sequential $\delta^{18}O$ and $\delta^{13}C$ series. The $\delta^{13}C$ values generally vary across the sequence according to the $\delta^{18}O$ values, except in two individuals. Specimens 2017-2 and 2020-56 present high values of carbon when the oxygen values are low (cold season).

4. Discussion

4.1. The faunal spectrum and mortality profiles

The predominance of caprines (sheep and goats) has been reported at Iron Age sites in the Languedoc region (e.g., Gardeisen, 2010; Forest, 2013; Nieto-Espinet et al., 2020), just as in neighbouring areas such as present-day Catalonia and Provence (e.g., Valenzuela-Lamas, 2008; Albizuri et al., 2010; López et al., 2011; Colominas et al., 2011; Vuillien and Gourichon, 2019; Nieto-Espinet et al., 2021a). The archaeozoological analysis of *Lattara* zone 1 shows the predominance of caprines in the 6th-5th centuries BC, followed by pigs and cattle. A similar trend has been identified in Zone 27 of the same settlement (Porcier, 2012), at La Monédière (Nieto-Espinet et al., 2020), La Condomine VII (Forest, 2013), and Le Cailar (Gardeisen, 2002; Creuzieux, 2009). The inland site of Plan de la Tour also reflects this trend (Lespes, 2020). However, at other sites located near the coast, such as Salses (Columeau, 2002), Mèze (Columeau, 2004) and other zones of *Lattara,* excluding zones 1 and 27 (Nieto-Espinet et al., 2020), a greater presence of cattle has been identified. Some authors have suggested that this may be a consequence of the cattle's greater need for water and fresh grazing, since natural freshwater was present in the coastal areas (e.g., Gardeisen, 2010). For the first phase analysed (c. 6th-5th centuries BC), it

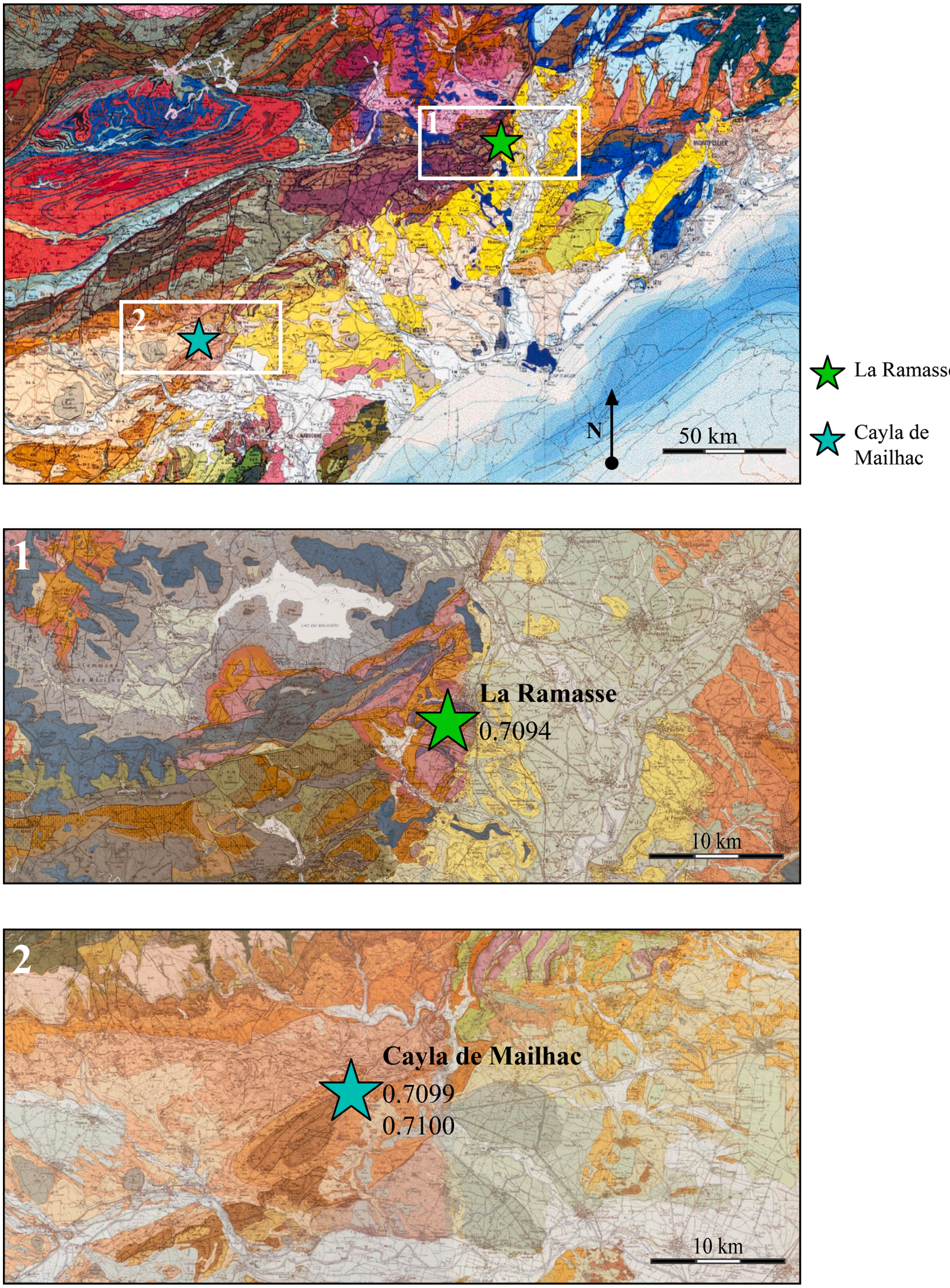

Fig. 7. Location of Cayla de Mailhac and La Ramasse in a geologic map of southern France. Source: European Geological Data Infrastructure. Surface visualization age (INSPIRE). EGDI 1:1M-scale surface Geologic Unit, Lithology portrayal. European dataset harvested from national INSPIRE WFS for geologic units.

was only possible to analyse the mortality profiles of *Lattara* Zone 1. The results indicate that caprines were predominantly slaughtered before they reached 48 months of age, with a representative peak at 6–12 months. This suggests the exploitation of tender meat and milk. The data is consistent with that obtained at the La Monédière site (Nieto-Espinet et al., 2020). The cattle at *Lattara* were slaughtered prior to 48 months, suggesting a management approach oriented towards intensive meat production and, to a lesser extent, milk. Again, the same trend was observed at La Monédière (Nieto-Espinet et al., 2020).

In the 5th-4th centuries BC, caprines were still the predominant species, followed by pigs and cattle. In inland *oppida*, there was increased pig exploitation, as observed at Cayla de Mailhac and La Ramasse (30–40% NISP). The easy management of these animals in the *oppida* (perched settlements in hills), and the higher demand for meat

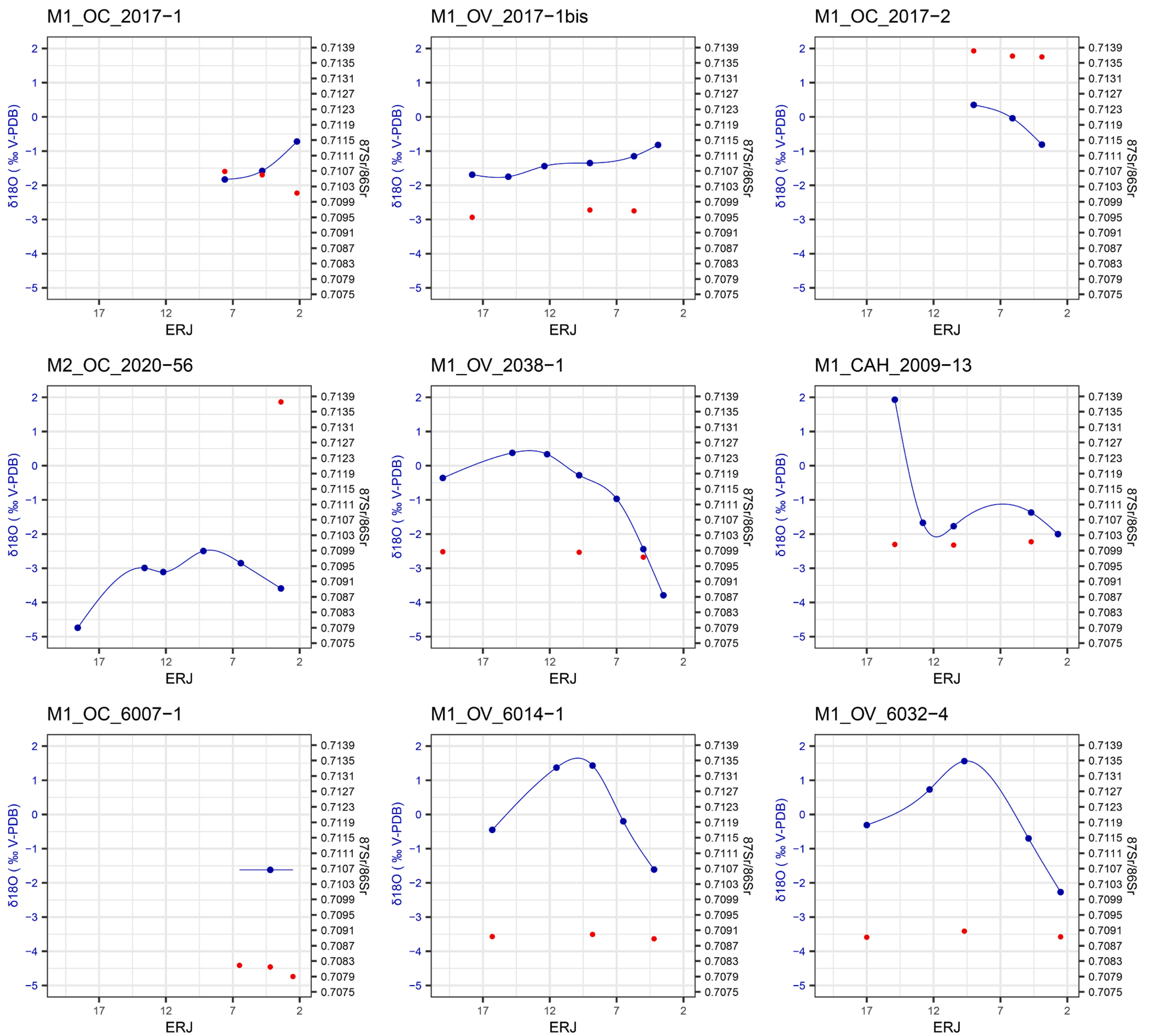

Fig. 8. Oxygen ($\delta^{18}O$; blue curve) and strontium isotope ratios ($^{87}Sr/^{86}Sr$; red dots) of enamel bioapatite of archaeological sheep (OV), goat (CAH) and caprine (OC) teeth from Cayla de Mailhac and la Ramasse. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

could explain this increase in pig breeding. At Cayla de Mailhac and in *Lattara* Zone 1, the slaughter of caprines was focused on meat exploitation (6–24 months) and, to a lesser extent, milk (24–48 months). In the La Ramasse *oppidum*, caprines were slaughtered when they were more than 48 months old, probably due to milk and wool exploitation. In the case of cattle, the exploitation of young specimens (6–24 months) to obtain tender meat, and adults (24–72 months), for meat and milk production have been observed at all the sites analysed.

4.2. Animal feeding strategies

In this paper, we analysed the feeding strategies of sheep, goats, and cattle using a multiproxy approach to five archaeological sites in the Languedoc region, spanning two chronological phases of the Iron Age.

For the first chronological period (6th-5th centuries BC), the dental mesowear and microwear analyses present a similar pattern. The dental mesowear shows a lower degree of abrasion in caprines (sheep and goats) than in cattle. These results suggest a mixed feeding regime with a tendency to browse in caprines and a grazing diet in cattle. The dental microwear analysis coincides with the results obtained through mesowear analysis: the cattle followed a grazer-type diet while the caprines had a mixed feeding regime. This variability between sheep and goat diets could only be analysed using dental microwear analysis. The results show different, although not significant, tendencies between these species. The enamel surfaces of sheep teeth have more scratches and fewer pits than those of the goats, suggesting that the goats ate more woody plants and shrubs, while the sheep consumed more grass plants. This is consistent with known feeding behaviour differences between sheep and goats (e.g., Animut et al., 2005). This trend has also been observed in previous isotope (Balasse, 2002) and dental microwear analyses. Evidence for the latter case has been found at Iron Age sites in the north-eastern Iberian Peninsula (Jiménez-Manchón et al., 2019; Ibáñez et al., 2020).

In the second chronological period (5th-4th centuries BC), dental microwear and mesowear analyses also reveal different dietary regimes: the cattle are grazers while the caprines are mixed feeders. For this

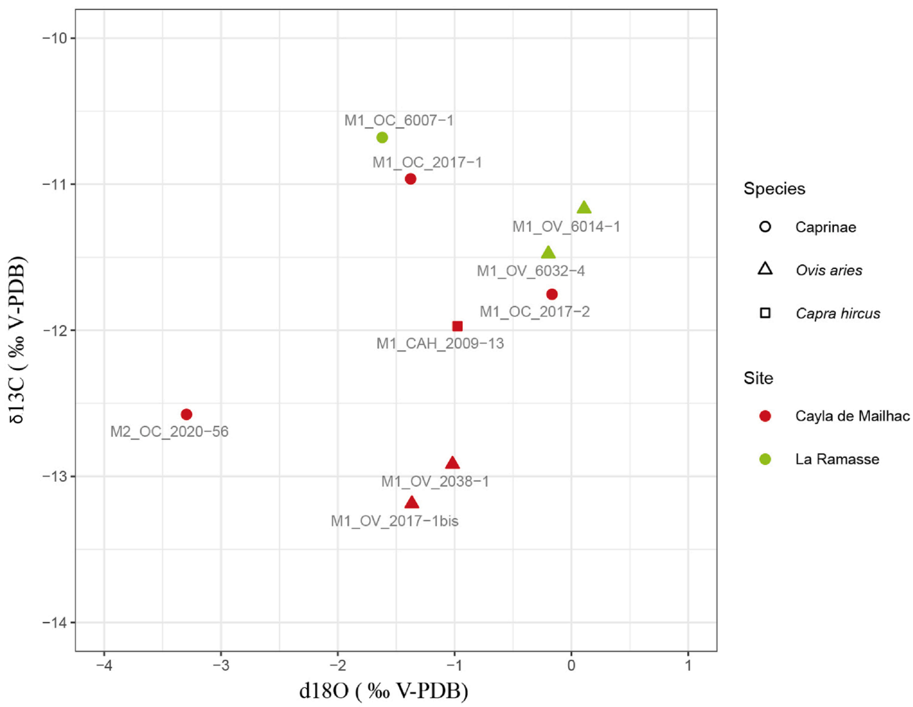

Fig. 9. Average of oxygen ($\delta^{18}O$) and carbone ($\delta^{13}C$) isotope analyses of tooth enamel bioapatite per individual (sheep (OV), goat (CAH) and caprine (OC) teeth) from Cayla de Mailhac and la Ramasse.

chronological phase, we used dental microwear to analyse the differences between areas located near the coast and the inland sites. The caprines and cattle from the sites located inland (Cayla de Mailhac and La Ramasse) present a greater number of pits than those from near the coast (La Monédière, *Lattara* and Le Cailar). This could be related to the animals feeding in eroded environments (Solounias and Semprebon, 2002). The ingestion of silicate particles, which cause a high number of pits and are related to overgrazing, could be the cause of this distinction (Healy and Ludwig, 1965; Healy, 1967; Mainland, 2006, 2007). Moreover, at the inland sites (i.e., Cayla de Mailhac and La Ramasse), a greater presence of goats has been reported, these species being better adapted to eroded environments (Orengo and Knappett, 2018). This supports the hypothesis of different feeding regimes according to the geographical area and, therefore, local livestock. The high number of pits on the teeth of animals from inland sites could also be explained by the ingestion of additional fodder supplies (Semprebon et al., 2011; Rieau, 2014; Gallego et al., 2020).

The carbon values obtained for the caprines from La Ramasse and Cayla de Mailhac are consistent with the consumption of C3 plants, suggesting a predominant consumption of woody and herbaceous vegetation that was available in the areas surrounding the site. The only second molar analysed is enriched in $\delta^{13}C$ compared with $\delta^{18}O$ (Fig. 10, M2_OC_2020-56, ERJ = 19 and 12), which could indicate a supplement of fodder during the cold seasons (e.g., Makarewicz and Pederzani, 2017).

Despite the difficulty of integrating dental wear and isotope analyses –as they reflect different moments in the lives of the individuals– these results are fully consistent with those obtained through the dental meso- and microwear analyses, which have revealed a mixed feeding dietary regime with a tendency towards browsing. The palaeoenvironmental data show the predominance of a forest mass of, for example, birch (*Betula pendula*), beech (*Fagus sylvativa*), hazel (*Corylus* sp.), or pine (*Pinus* sp.) (Liottier et al., 2017).

In both chronological periods, the caprines and cattle present different dietary regimes: the cattle were grazers while the caprines were mixed feeders at both inland sites and those located near the coast. This would indicate that the cattle would have grazed in more grass-rich areas, while the caprines would have fed in more wooded areas. This scenario is compatible with the hypothesis proposed in previous work (e.g., Nieto-Espinet et al., 2020) that suggested different pastoral management approaches for caprines and cattle, probably due to agricultural pressure on livestock practices.

4.3. Animal mobility

Strontium and oxygen isotope ratios have been used to determine the seasonal mobility of animals at the two inland archaeological sites: Cayla de Mailhac and La Ramasse. At Cayla de Mailhac, four out of the six caprine individuals studied present strontium isotope ratios consistent with the local geological stratum (Cenozoic sediment) during the period of enamel mineralisation. This suggests that these specimens grazed on areas close to the site throughout the year. Two specimens (2017-2 and 2020-56) have radiogenic strontium isotope ratios consistent with Lower Palaeozoic sediments, found further away, in areas like the Massif Central (ca. 15 km). The homogeneity of the strontium isotope ratios in 2017-2 suggests that this individual grazed on those distant areas throughout the period of tooth mineralisation. This suggests that these two animals (2017-2 and 2020-56) arrived at the site as adults, when they were sexually mature, i.e., at 12 months or older.

At the La Ramasse site, only three individuals were analysed. Two out of the three present values consistent with the local geological substratum throughout tooth mineralisation. A third specimen shows Sr isotope values that, although compatible with Mesozoic sediments present at the site, are lower than those measured for the two other individuals. This could potentially suggest that this animal had lived in another area of the Cevennes mountains.

The results of this work suggest that the animals predominantly grazed in the areas close to the sites in which they were found, in the hinterland of the Languedoc region, with no long-distance seasonal movements. However, two individuals grew up, during the period of M1 mineralisation, in other regions, suggesting that some animal mobility did occur. Despite the small number of specimens analysed, these results

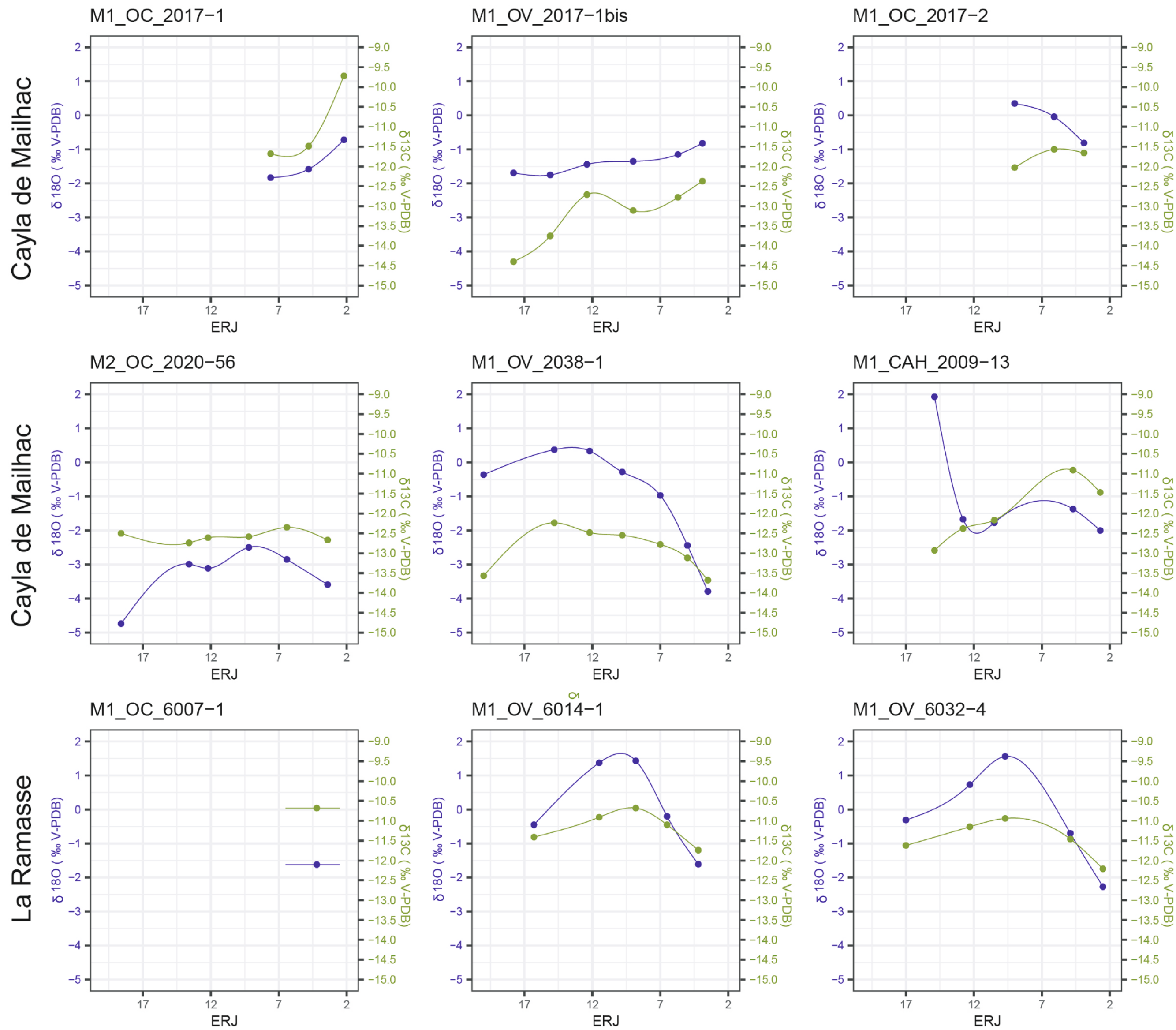

Fig. 10. Oxygen ($\delta^{18}O$) and carbone ($\delta^{13}C$) isotope analyses of tooth enamel bioapatite of archaeological sheep (OV), goat (CAH) and caprine (OC) teeth from Cayla de Mailhac and la Ramasse.

suggest greater animal mobility in the hinterland compared to the coast (Nieto-Espinet et al., 2020).

5. Conclusion

In this paper, we present a multiproxy approach (zooarchaeology, dental mesowear, dental microwear, and strontium, carbon and oxygen isotope analyses) to address the issue of animal diet and mobility in the Languedoc region (southern France) during the Iron Age (6th-5th centuries BC and 5th-4th centuries BC).

As observed in previous work, caprines are the predominant taxa, followed by pigs and cattle. Mortality profiles suggest that the domestic herds were reared for their meat and, to a lesser extent, milk. At the *oppida* of Cayla de Mailhac and La Ramasse, there was a notable presence of pigs. The ease of managing these animals at the *oppida* (settlements perched on hills), and the greater demand for meat could explain this increased consumption of pigs compared to the coastal site.

Dental meso- and microwear analyses reveal that caprines and cattle had different dietary regimes. On the one hand, the cattle had a diet rich in grasses, and, on the other hand, the caprines were mixed feeders with a tendency to browse. These results support the hypothesis of different animal management strategies in Iron Age times according to the species: the cattle could have grazed on grassland and the caprines (sheep and goats) could have fed in more wooded areas. The comparison between inland and coastal sites reveals a dental microwear pattern compatible with a greater soil intake at the inland sites, suggesting the presence of more eroded areas. The higher frequencies of goats at the inland sites, a taxon better adapted to eroded environments, could also be linked to this. Furthermore, the different dental microwear pattern according to the geographical area supports the hypothesis of local livestock breeding. Our results also support the hypothesis that the expansion of agriculture and its pressure on livestock led herders to feed caprines –which have a more flexible diet– in wooded, probably poorer quality areas that were less suitable for agriculture. This is coherent with the presence of the pathologies, possible animal malnutrition, and inbreeding attested to in previous works (e.g., Nieto-Espinet et al. 2020).

The results of the isotope analyses suggest the absence of large-scale animal movements in the hinterland of the Languedoc region. However, some animal mobility was evidenced (i.e., open-air rearing in areas close to the sites and the presence of animals reared on other geological formations). Comparing the results obtained in this paper with those of a previous study that addressed animal mobility in the coastal area (Nieto-Espinet et al. 2020), it appears that there was more animal mobility in the hinterlands than at the coast. A greater number of teeth are needed in future works to validate this hypothesis.

The combination of a multiproxy approach has been able to contribute to the comprehension of animal husbandry in Iron Age Languedoc. The different animal feeding strategy and the absence, or very little, animal mobility provides valuable information about the socio-political context of territoriality in Iron Age north-western Mediterranean. The application of this multiproxy approach in previous and later chronological periods, as well as in neighbouring geographical areas, will allow us to have a diachronic and broader vision of the animal feeding strategies and its relationship with the socio-political context.

CRediT authorship contribution statement

Sergio Jiménez-Manchón: Conceptualization, Methodology, Formal analysis, Software, Visualization, Writing – original draft. **Sílvia Valenzuela-Lamas:** Conceptualization, Methodology, Software, Visualization, Writing – review & editing. **Ariadna Nieto-Espinet:** Conceptualization, Visualization, Software, Writing – review & editing. **Delphine Bosch:** Methodology, Writing – review & editing. **Nicolas Patris:** Methodology, Writing – review & editing. **Armelle Gardeisen:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary material

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